B. ASSESSMENT OF BLUEFISH (SAW/SARC-41)

A report of the ASMFC Technical Committee/Assessment Subcommittee, SAW-41

EXECUTIVE SUMMARY

Bluefish, *Pomatomus saltatrix*, is a migratory pelagic species found in most temperate and tropical marine waters throughout the world. Along the U.S. Atlantic Coast, bluefish commonly occur in estuarine and continental shelf waters. Bluefish are a schooling species that migrate in response to seasonal changes, moving north and inshore during the spring and south and offshore in the late autumn. The Atlantic bluefish fishery is believed to exploit a single stock or population of fish.

Bluefish is one of the most sought after species in the recreational fisheries along the Atlantic Coast. In 2004, recreational anglers along the Atlantic Coast harvested over 6.9 thousand metric tons (mt) of bluefish, second only to striped bass (11.7 thousand mt harvested). Recreational catch of bluefish has averaged over 19 thousand mt since 1982. Landings from the commercial bluefish fishery have been consistently lower than the recreational catch. Regional variations in commercial fishing activity are linked to the seasonal migration of bluefish. Bluefish are most abundant in the North and Mid-Atlantic from late spring to early fall, when the majority of commercial fishing activity for bluefish in these areas occurs. In the late fall and winter, bluefish move southward and landings peak in the South Atlantic region. Annually, the majority of commercial landings are taken in the Mid- and South Atlantic regions where approximately 87% of the coastwide total landings have occurred since 1950.

The Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fisheries Management Council (MAFMC) jointly manage bluefish under Amendment 1 to the Bluefish Fishery Management Plan (FMP). The FMP defines the management unit as bluefish occurring in U.S. waters of the western Atlantic Ocean and is considered a single stock of fish. The FMP allows a state-by-state commercial quota system and recreational harvest limit to reduce fishing mortality. ASMFC and MAFMC adjust both quotas annually by the specification setting process. Overfishing definitions are based on F_{msy} and B_{msy}.

The Bluefish Technical Committee examined the quality of the commercial, recreational, and age data for use in an analytical model. The committee felt the level of sampling by gear and market grade from North Carolina and Virginia was adequate to characterize the length distribution of Atlantic coast bluefish landings. The level of commercial sampling in certain time periods was low, however the committee felt there was enough information covering the entire time series to capture the trends in size for landings since 1982. The Committee concluded that the recreational landings information was adequate for use in a bluefish assessment. Recreational discard estimates were also sufficient although there remains a lack of discard length information. Age information, although relatively sparse in some years, was determined adequate to characterize bluefish catch and indices.

The Committee decided an age-structured model was the best approach given the available data and suggestions from previous SAW reports. The committee felt that a VPA model produced satisfactory results, but the assumption of no error in the catch-at-age matrix and the ADAPT method of modeling selectivity could produce misleading results. Therefore, a catch-at-age model, ASAP from the NFT models, was used as the primary assessment tool. The ability of the ASAP model to allow error in the catch-at-age as well as the assumption of separability into year and age components makes it better suited to handle the selectivity patterns and catch data from the bluefish fishery.

The biological reference points established in Amendment 1 were based on the results of a biomass-dynamic model, ASPIC, which had been used to assess the bluefish stock in the past several years. New reference points are proposed based on the results of the catch at age model. The model software estimates $F_{msy} = 0.19$. Biomass reference points were developed by applying ASAP model results to a Thompson-Bell Yield-Per-Recruit model. The Shepherd-Sissenwine approach was used to estimate B_{MSY} at 147.05 million lbs; the current estimate of bluefish stock biomass is 104.1 million lbs. The ASAP model estimated F_{MULT} in 2004 to equal 0.149. The ASAP model results lead to the conclusion that the Atlantic stock of bluefish is not experiencing overfishing. The current FMP defines an overfished condition as ½Bmsy which equals 73.5 million lbs. The current biomass estimate implies that bluefish are not overfished.

1.0 TERMS OF REFERENCE

1. Evaluate adequacy, appropriateness, and uncertainty of fishery-dependent and fishery-independent data used in the assessment.
2. Evaluate adequacy and appropriateness of models used to assess the stock and to estimate population benchmarks.
3. Evaluate and/or update biological reference points as appropriate.
4. Estimate and evaluate stock status (biomass) and fishery status (fishing mortality rates).
    a. Is the stock overfished?
    b. Is overfishing occurring?
5. Develop recommendations for improving data collection and for future research.

2.0 INTRODUCTION

The Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council (MAFMC) jointly developed the Fishery Management Plan (FMP) for the bluefish fishery and adopted the plan in 1989 (ASMFC 1989; Moore 1989). The

Secretary of Commerce approved the FMP in March 1990. The FMP defines the management unit as bluefish (*Pomatomus saltatrix*) in U.S. waters of the western Atlantic Ocean.

The ASMFC and MAFMC approved Amendment 1 to the FMP in October 1998 and the National Marine Fisheries Service (NMFS) published the final rule to implement the Amendment 1 measures in July 2000 (MAFMC and ASMFC 1998). Amendment 1 implemented an annual coastwide quota to control bluefish landings. The ASMFC and MAFMC adjust the quota and harvest limit annually using the specification setting process detailed in Amendment 1. The recreational fishery is allocated 83% of the entire quota. Coastwide, the commercial fishery is limited to 17% of the total allowable landings each year. The commercial quota can be increased if it is anticipated that the recreational fishery will not land their entire allocation for the upcoming year. The coastwide commercial quota is divided into individual state-by-state quotas based on landings from 1981-1989.

2.1 Life History

Bluefish, *Pomatomus saltatrix*, is a coastal, pelagic species found in temperate and tropical marine waters throughout the world (Goodbred and Graves 1996; Juanes et al. 1996). Bluefish spawn in offshore waters (Kendall and Walford 1979; Kendall and Naplin 1981). Larvae develop into juveniles in continental shelf waters and eventually move to estuarine and nearshore shelf habitats (Marks and Conover 1993; Hare and Cowen 1994; Able and Fahay 1998; Able et al. 2003). Bluefish are highly migratory along the U.S. Atlantic coast and are found north of the Carolinas only in warmer months (Beaumariage 1969; Lund and Maltezos 1970).

2.2 Growth

Several studies show bluefish to be a moderately long-lived fish with a maximum age of 14 years (Hamer 1959; Lassiter 1962; Richards 1976; Barger 1990; Chiarella and Conover 1990; Terceiro and Ross 1993; Austin et al. 1999; Salerno et al. 2001; Sipe and Chittenden 2002). Bluefish up to 88 centimeter (cm) fork length (FL) have been aged (Chiarella and Conover 1990; Salerno et al. 2001). Terceiro and Ross (1993) noted considerable variation in mean bluefish size-at-age. Scale ages have been used to estimate von Bertalanffy growth parameters (Lassiter 1962; Barger 1990; Terceiro and Ross 1993; Salerno et al. 2001). The values for L_∞ from these studies (87-128 cm FL) match closely to the largest individuals in catch data. Growth rates do not differ between sexes (Hamer 1959; Salerno et al. 2001).

Bluefish grow nearly one-third of their maximum length in their first year (Richards 1976; Wilk 1977). Variation in growth rates or size-at-age arise among young bluefish from the appearance of intra-annual cohorts. Lassiter (1962) identified a spring-spawned cohort and a summer-spawned cohort from the bimodal appearance of size at Annulus I for fish aged from North Carolina. As the cohorts appellations imply, the seasonal cohorts differ in age by two to three months. Summer-spawned larvae and juveniles grow faster than spring-spawned larvae and juveniles (McBride and Conover 1991). Size differences at annual age diminish greatly after three to four years (Lassiter 1962).

2.3 Reproduction

Bluefish spawn offshore in the western North Atlantic Ocean, from approximately Massachusetts to Florida (Norcross et al. 1974; Kendall and Walford 1979; Kendall and Naplin 1981; Collins and Stender 1987). In addition to the spring and summer cohorts identified by Lassiter (1962), Collins and Stender (1987) identified a fall-spawned cohort, demonstrating an expansive and prolonged bluefish spawning season. Individual bluefish are thought to be highly iteroparous but no specific information is published for spawning frequency or batch fecundity.

2.4 Stock Definitions

Bluefish in the western North Atlantic is managed as a single stock (NEFSC 1997; Fahay et al. 1999). Genetic data support a unit stock hypothesis (Graves et al. 1992; Goodbred and Graves 1996; Davidson 2002). For management purposes, the ASMFC and MAFMC define the management unit as the portion of the stock occurring along the Atlantic Coast from Maine to the east coast of Florida.

2.5 Habitat Description

Adult and juvenile bluefish are found primarily in waters less than 20 meters (m) deep along the Atlantic coast (Fahay et al. 1999). Adults use both inshore and offshore areas of the coast and favor warmer water temperatures although they are found in a variety of hydrographic environments (Ross 1991; Fahay et al. 1999). Temperature and photoperiod are the principal factors directing activity, migrations, and distribution of adult bluefish (Olla and Studholme 1971).

3.0 DESCRIPTION OF FISHERIES

3.1 Commercial Fishery

Commercial landings from the bluefish fishery have been consistently lower than the recreational catch (Table 1; Figure 1). Gill nets are the dominant commercial gear used to target bluefish and account for over 40% of the bluefish commercial landings from 1950 to 2003. Other commercial gears including hook & line, pound nets, seines, and trawls, collectively account for approximately 50% of the commercial landings.

Regional variations in commercial fishing activity are linked to the seasonal migration of bluefish. The majority of commercial fishing activity in the North and Mid-Atlantic occurs from late spring to early fall when bluefish are most abundant in these areas. As water temperatures decrease in late fall and winter, bluefish migrate south. Peak landings in the South Atlantic occur in late fall and winter. The majority of commercial landings are taken in the South and Mid-Atlantic regions (Table 2). Since 1950, approximately 87% of the coastwide total landings have been taken in these regions.

Commercial landings decreased from 7,500 mt in 1981 to 3,300 mt in 1999 (Table 1; Figure 1). Commercial landings have been regulated by quota since implementation of Amendment 1 in 2000. In 2000 and 2001, landings increased to approximately 3,600 mt and 3,900 mt, respectively, but declined again in 2002 and 2003 to at 3,100 mt and 3,400 mt, respectively (Table 1; Figure 1). Preliminary landing estimates for 2004 increased to 3,800 mt (Table 1).

3.2 Recreational Fishery

Bluefish is a highly sought after species in the recreational fisheries along the Atlantic Coast. Recreational catch of bluefish has averaged over 19,000 metric tons (mt) since 1981 (Table 1, Figure 2). In 2004, recreational anglers along the Atlantic Coast harvested over 6,800 mt of bluefish. Most of the recreational activity occurs from July to October, when almost 70% of the bluefish harvest is taken (Figure 3) . Most of the recreational catch of bluefish is taken in the North and Mid-Atlantic states (New York to Virginia) (Table 3). Recreational landings decreased from 43,500 mt in 1981 to a low of 5,379 mt in 1999. Since 1999, landings and numbers have fluctuated from about 6,200 mt to about 8,000 mt. Landings in 2004 were 6,870 mt (Table 1; Figure 2).

4.0 TERM OF REFERENCE #1: Evaluate adequacy, appropriateness, and uncertainty of fishery-dependent and fishery-independent data used in the assessment.

This bluefish assessment is an extension of the stock analysis reviewed in 1997 and accepted at SAW-23. The Bluefish Stock Assessment Working Group therefore concluded that information through 1995, the final year in the SAW-23 assessment, was adequate for use in an age-based assessment model. Expanded numbers at length for commercial and recreational fisheries were subsequently updated through 1996. Data from 1997 to present were assembled and reviewed for adequacy by the current working group.

4.1 Commercial Data

Commercial fisheries landings data for states between North Carolina and Maine are collected via the NMFS dealer mandatory reporting system. Beginning in June 2004, an electronic dealer reporting was initiated in the northeast. The states of Florida, Georgia, and South Carolina use a trip ticket system.

4.1.1 Commercial Biological Sampling

Commercial length data from 1997 to 2004 were expanded based on four regions of sampling: Maine to Maryland, Virginia, North Carolina, and South Carolina to Florida.

4.1.1.1 Maine to Maryland

Biological samples collected by NMFS were used to expand landings by year, quarter, gear, and market category. Length data were measured to the nearest cm FL and total landings in weight in pounds (lbs). Lengths were converted to weights using a seasonal length-weight equation across all years. Missing information in cells was replaced by mean weights in adjoining cells (e.g. among gears by market category, quarter). If no appropriate information was collected within a year, overall cell mean weights were substituted from the 1997 to 2004 period.

Sampling levels, landings and samples per 100 lbs of landings are presented in Tables 4 to 6. Since 1997, sampling in this region has averaged only 1,766 lengths per year (1,376 excluding the 4,500 lengths from 2004). The seasonal distribution of samples varied by year, although in general few samples were collected during the first quarter. Similarly, all market grades were not sampled equally among seasons or years.

4.1.1.2 Virginia

The Virginia Marine Resources Commission's (VMRC) Stock Assessment Program (SAP) has collected finfish biological data (length, weight, sex, and age) since 1988. At most sites, bluefish are sampled from 50-pound boxes of landed fish that have been graded, boxed, and iced. At sites associated with pound net or haul seine landings, bluefish are intercepted after they have been graded by market category and weighed. A 50-pound box (or partial box) of graded fish from all available species market categories (*i.e.* small, medium, large, and unclassified) are chosen for determination of length, weight, and sex information. In most cases, the entire 50-pound box of fish graded by species market category is sampled to account for within-box variation (see Chittenden et al. 1990).

Each fish is measured for size (total length and usually weight). Weight is measured to the nearest 0.1 lbs; total length is measured to the nearest millimeter (mm), accurate to 2.5 mm, using electronic Limnoterra Fish Measuring Boards. Fork length is measured on a subsample basis. All fish, except those with damaged tails, are measured for total length from the tip of the snout to the end of the tail fin.

Ancillary data collected for each biological sample includes species grade or market category, harvest area, gear type used, and total catch by species market category. Biological data collections are generally stratified by season, area, gear type, and market grade. Numbers of fish sampled depends on availability but range from roughly 5,000 (1989-1992) to about 2,000 (2000-2003). Sampling intensity ranged from 25.8 lbs per 1,000 lbs of landings (2003) to 4.5 lbs sampled per 1,000 lbs of landings (1995) from 1989 to 2003. Generally, a greater proportion of the landings are sampled during years of lower landings. A summary of samples collected, landings and sampling per unit weight are provided in Tables 4 to 6.

4.1.1.3 North Carolina

Commercial bluefish landings are monitored through the North Carolina trip ticket program (1994-present) (NCDMF 2004). Under this program, licensed fishermen can only sell commercial catch to licensed North Carolina Division of Marine Fisheries (NCDMF) fish dealers. The dealer is required to complete a trip ticket every time licensed fishermen land fish. Trip tickets capture data on gears used, area fished, species harvested, and total weights of each individual species landed, by market grade. Trip tickets are submitted to NCDMF monthly.

Fishery-dependent sampling of NC commercial fisheries has been ongoing since 1982. Predominant gears sampled include: ocean sink nets, estuarine gill nets, winter trawls, long haul seines/swipe nets, beach haul seines, and pound nets. From the fishery-dependent data, NCDMF derives length and weight estimates by market grade for almost all of the commercial landings except catches by shrimp trawls, pots, long line, gigs, fyke nets, hand harvest, trolling, and rod & reel. Landings from these unsampled or 'other' commercial gears combined represent 0.2-1.1% of the 1997-2004 landings. Length frequency distributions from all sampled commercial gear were combined to represent landings by these other gears.

Bluefish length frequency samples, by gear, for both the market and bait components were obtained from dealers with a sample representing the landings from an individual trip. Sampling was done by market category as fish were culled at the dealers. Length distributions (and aggregate weights) from sampled trips by gear and market grade were expanded by respective landings, gear, and market grade. Length frequency distributions were combined to represent total landings, by gear, market grade, quarter, and year.

Length frequency distributions, by gear, market grade, quarter, and year, were used to proportion the total number of individuals harvested into numbers at length. Due to the lack of available data for the jumbo market grade, large and jumbo market grades were combined. When length information was insufficient, data from bluefish caught from inside waters by long haul seines, estuarine gill nets, or pound nets, or the ocean beach seine fishery, were substituted for each other.

Bait was defined as the part of the catch not marketed for human consumption, but sold for crab or fish pot bait, industrial uses, or discarded. Bait landings were estimated bi-annually by applying the bi-annual ratio of marketable to bait species sampled in the fish house to the reported marketable landings. The total number of bait individuals by fishery was derived by dividing the estimate of bait landings by the mean weight of a bait individual for each fishery, for each bi-annual period. A summary of samples collected and sampling per unit weight are provided in Tables 4 to 6. Since 1997, NC has averaged 7,650 length measurements per year covering all seasons and market grades.

4.1.1.4 Florida

Biological data collection for the bluefish fishery from Florida to North Carolina was sparse. Florida Department of Environmental Protection (FLDEP) collected 724 lengths from a variety of gear types since 1998 (although 4,321 fish were measured between 1993 and 1997 prior to a change in fishery regulations). The length distribution among periods was similar to NC medium grade bluefish, consequently the NC medium length distribution was used to expand semi-annual FL landings (Figure 4).

Expanded commercial fisheries length frequencies among all sampling programs are presented in Figure 5.

4.2 Commercial Discards or Bycatch

The SAW-23 assessment concluded that commercial discards were minimal and not estimable based on available data. The bluefish stock assessment working group concluded that discard estimates for the Atlantic coast were not possible and likely insignificant for several reasons. First, there is no minimum fish size in the commercial fishery. Second, the average commercial quota for the 1994-2003 period was approximately 10 million lbs while an average 8.1 million lbs was landed in the same time period. Third, the bluefish FMP allows states with a surplus quota to transfer a portion or the entire quota to a state that has or will reach its quota. Finally, Amendment 1 allows quota transfer from the recreational fishery to the commercial fishery.

4.3 Recreational Data

Recreational fishery statistics for bluefish caught along the Atlantic Coast were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS). The MRFSS estimates are divided into three catch types:

1) Fish brought to the dock in whole form and are identified and measured by trained interviewers are classified as landings (Type A).
2) Fish that are not in whole form (*e.g.* bait, filleted, released dead) when brought to the dock are classified as discards (Type B1). Discards are reported to the interviewer but identified by the angler.
3) Fish released alive (Type B2) are identified by the angler and reported to the interviewer.

The sum of types A and B1 provides an estimate of total harvest for the recreational fishery. Total recreational catch is the sum of the three catch types (A + B1 + B2). Estimates of weight provided by MRFSS are minimum values and may not accurately reflect the true total weight that was landed or harvested. This bias is more common with large or rarely caught species.

Length and weight measurements of type A catch are collected as part of the MRFSS intercept survey program (Figure 6). The intercept survey collects catch and demographic information from recreational anglers who have just completed fishing. Sampling is stratified by state, mode (shore, private/rental, or charter/party), and two month wave, with a minimum of 30 intercepts per stratum. Numbers, weights, and lengths are recorded by species as part of the intercept interview. The intensity of length frequency sampling for bluefish from the recreational fishery was calculated on the basis hundreds of pounds landed per length measurement (NEFSC 1994a, 1994b, 1997). Sampling intensity by wave is presented in Table 7 for 1997 to 2004. Because there is no minimum size, the working group assumed that bluefish recreational discards had the same size distribution as landed fish. As in previous bluefish stock assessments, a discard mortality rate of 15% was assumed for type B2 catches based on Malchoff (1995) and as modified by the ASMFC Bluefish Technical Committee (NEFSC 1997).

4.3.1 Recreational Catch Rates

The MRFSS intercept and catch estimate data were used to develop a fishery-dependent time series of catch-per-unit-effort (CPUE). Recreational fishing effort was defined as those trips that either caught or targeted bluefish (*i.e.* variable 'PRIM1' or 'PRIM2' in MRFSS intercept files). Bluefish catch was also divided by the number of participants per trip to produce catch per angler trip as a measure of effort. The different measurements of effort had little effect on the time series trends (Figure 7). Based on the recommendation of previous SARC reviews, the CPUE time series was modeled in a general linear model framework using a negative binomial transformation of log catch rates (per trip) (Terceiro 2003). Significant variables in the model include year, wave, area, mode of fishing, and number of fishing days in the previous 12 months as recalled by anglers. Re-transformed year estimates from the GLM model were used as the recreational CPUE time series. A comparison of CPUE series before and after GLM modeling is shown in Figure 7. The amount of information available as covariates in the GLM is limited and has had little influence on the time series. .

4.3.2 Age Data

NCDMF age data were available for bluefish aged by scales (1983-1996; n=5,639) and otoliths (1996-2000; n=2,067). The majority of the age structures were collected from fishery-dependent sampling, but a few recreationally caught bluefish were also aged. Age data were also provided for age structures (scales, whole, and sectioned otoliths) collected from various northeast states (1996; n=295). The northeast samples were collected from commercial and recreational gear (hook & line, trawl, seine, and gill nets).

In 1997, VMRC established a cooperative fish ageing lab with Old Dominion University's Center for Quantitative Fisheries Ecology (CQFE) Laboratory. The CQFE Lab age harvest from Virginia's marine fisheries and provide the data to VMRC for management purposes. Otolith-based age data were available for bluefish from 1998-2004. Collection of age samples was based on a quota by inch interval. The Virginia time series (1998-2004) contains age information by gear, sex, market category, and location from approximately 2,500 samples, from sectioned otoliths only.

The bluefish stock assessment working group reviewed the NC age data and concluded that there was a shift in ageing protocol after 1997. From 1998 on, the time of annuli formation appears to be the criteria for birth date rather than January 1. Consequently the spring age data from 1998-2004 were incompatible with other available age data and could not be modified without supplemental information. Therefore, only age keys provided by VA from 1998 to 2004 were applied to commercial and recreational fisheries.

Several studies document the problems with bluefish ageing information, specifically problems with using scales to accurately age bluefish. False annuli, rejuvenated scales, identifying annuli on scales from larger fish, different annuli counts between scales from the same fish, and the timing of the first annulus formation can all cause inaccuracies (Lassiter 1962; Richards 1976; NCDMF 2000). The divergence between scale ages and otolith ages occurs beyond age-6 (E. Robillard, CQFE, pers. comm. 2005). Therefore the catch-at-age matrices were truncated to a 6+ category to reduce ageing error associated with scale ages in the 1982-1997 time period.

The SAW-23 review expressed concern that use of a single age key collected in NC may not be representative of the coastal stock (NEFSC 1997). Salerno et al. (2001) examined age data collected along the Atlantic coast in the NEFSC autumn trawl survey and compared the scale ages with the North Carolina commercial ages and concluded that the NC ages were representative of Atlantic coast bluefish. Other studies have used age-length information from commercial and recreational fisheries and fishery-independent surveys and have shown similar bluefish growth parameter estimates from Maine to North Carolina, providing further evidence that North Carolina age data are representative of the Atlantic Coast (VMRC 1999, 2000, 2001).

In years with a limited number of ages available, seasonal age keys were combined across years. Spring age keys were developed for 1997 (n=228), 1998-2001 combined

(n=62), 2002 (n=282), and 2003 (n=226). Spring 2004 (n=41) was a combination of 2003 and 2004 (Table 8). Fall age keys were developed for 1997 (n=217), 1998-1999 combined (n=337), 2000-2001 combined (n=412), 2002 (n=395), 2003 (n=214), and 2003-2004 combined (n=380) (Table 8). To fill gaps in the keys, the working group assumed that length bordered by lengths with only one age group were similar. Lengths with no available information were filled from an age key for the combined 1997-2003 period. Indices were divided by age using survey specific age data if available (CT 1984-1998 and NMFS 1997-1998), otherwise the general age key was applied.
Commercial catch at age and recreational catch at age were combined for the 1982 to 2004 catch at age matrix (Table 9). Age data was also used to calculate mean weights at age (Table 10). Recreational CPUE estimates were also partitioned into ages (Table 11) based on the proportion of each age group in the recreational catch at age matrix

4.4 Fishery-Independent Surveys

Fishery-independent surveys from Florida to New Hampshire were reviewed for this assessment. Survey methods include estuarine and nearshore bottom trawl and beach seine surveys. The surveys caught predominantly age-0 and age-1 bluefish (< 30 cm FL). Bluefish catch was generally low and large catches were sporadic. Indices of relative abundance were calculated based on constraints of catch size, time, and location of sampling. Several surveys sample monthly or bi-monthly. The working group evaluated the timing of each survey and chose the period that had the highest availability of bluefish to the survey gear (Table 12).

4.4.1 Northeast Fisheries Science Center (NEFSC) Fall Inshore Trawl Survey

The NEFSC has conducted bottom trawl surveys over a large portion of the Atlantic shelf since 1963 (Avarovitz 1981). Sampling sites are randomly selected from within depth-defined strata; both inshore and offshore strata are sampled. The surveys run in the spring, fall, and winter seasons. The surveys cover areas from 5 to 200 fathoms deep, from Cape Hatteras, North Carolina to Canadian waters. The trawling locations are allocated according to a stratified-random sampling design. Strata 1-46 are assigned to the fall inshore survey for stations from Cape Hatteras to Cape Cod. The research vessels F/RV *Albatross IV* and the F/RV *Delaware II* are used exclusively to conduct these surveys. A small-mesh cod-end liner (1/2 inch mesh) is used to retain pre-recruits. Bluefish are seen more commonly in the fall survey and from inshore sites. Mean number per tow and mean weight per tow from the 1975-2004 fall inshore survey were calculated (Table 13; Table 14). Mean number per tow at length since 1982 were divided into age categories using NEFSC ages prior to 1996 (Table 15). Age keys developed from VA data were used for 1997 to 2004. The majority of bluefish caught in the fall are age-0 or age-1. The index shows a large cohort present in 1981, 1984, and 1989. The index has been well below the time series average since 1989, although the 2003 index was slightly above average (Table 13).

4.4.2 NEFSC Fall Offshore Trawl Survey

NMFS fall survey data from 1975 to 2004 were also used to calculate stratified mean number per tow and mean weight per tow (Table 13). Age expansion was done as discussed for the inshore strata (Table 15). Catch rates in the offshore strata were considerably lower and varied without trend.

4.4.3 Massachusetts Division of Marine Fisheries Inshore Bottom Trawl Survey

The Massachusetts Division of Marine Fisheries (MADMF) started sampling inshore state waters in 1978 using a bi-annual seasonal bottom trawl survey. The survey design is random stratified using strata based on geographic area and depth zone. Bluefish are rarely observed in the spring component of the survey and the majority of bluefish caught during the fall survey are young-of-year (<25 cm), with most catches representing the second or summer cohort fish. Arithmetic and geometric mean numbers and length frequencies for young-of-year are available for the 1978 to 2003 time period. Survey indices depict larger than average year-classes in 1987, 1991, 1997, and 1998. Recent year-class indices (2000-2002) are lower than average (Table 13).

4.4.4 Rhode Island Marine Fisheries Trawl Surveys

The Rhode Island Division of Fish and Wildlife's (RIDFW) Marine Fisheries Section initiated a seasonal trawl survey in 1979 to monitor recreationally important finfish stocks in Narragansett Bay, Rhode Island Sound, and Block Island Sound. The survey employs a stratified random, stratified fixed design and records aggregate weight by species, abundance, individual length measurements, and various physical data. In 1990, a monthly component was added to the survey, which includes 13 fixed stations in Narragansett Bay. Abundance indices were calculated from 1981-2004.

Age-0 fish dominate bluefish catch in the RIDFW seasonal survey during the fall component of the survey. The spring component rarely catches bluefish. The average abundance index for the RIDFW survey was 14.1 fish/tow. Relative abundance was below average from 1981-1993, ranging from 1.3 to 13.0 fish/tow. Relative abundance was highest in 1994 (36.9 fish/tow), 1997 (72.2 fish/tow), 1998 (46.7 fish/tow), and 1999 (61.2 fish/tow) before dropping to below average in the early 2000s. The lowest abundance index occurred in 2003 (0.9 fish/tow) and the most recent index (2004) is below average at 5.5 fish/tow (Table 13; Table 14).

4.4.5 Connecticut DEP Long Island Sound Trawl Survey

The Connecticut Department of Environmental Protection's (CTDEP) Marine Fisheries Division has conducted the Long Island Sound Trawl Survey (LISTS) since 1984. The LISTS was designed to collect long-term fishery-independent data from the Connecticut and New York waters of Long Island Sound. The LISTS employs a stratified-random sampling design using strata based on depth interval (0-9.0 m, 9.1-18.2 m, 18.3-27.3 m or, 27.4+ m) and bottom type (mud, sand, or transitional). Sampling is currently divided into spring (April, May, and June) and fall (September and October) periods. Forty tows are sampled monthly (120 in the spring, 80 in the fall) using a 14 m otter trawl (9.1 m headrope, 14 m footrope). Species are sorted, weighed, and counted and all or a sub-sample of primary species are measured to nearest cm FL. Scales are removed from a sub-sample for ageing purposes. The LISTS has not aged bluefish since 1988, however, scales from 2,469 bluefish were collected and aged from 1984 to 1988. Geometric mean number per tow estimates were developed from the September tows as an index of bluefish abundance. Mean number per tow at age since 1988 were developed using NC or VA age keys (Table 15).

The LISTS has collected 150,091 bluefish from 4,869 tows since 1984. The survey is one of the few inshore state fishery-independent surveys that consistently capture adult bluefish during the fall period. The LISTS calculates two geometric mean count and weight indices for the fall survey: an age-0 index (fish less than 30 cm) which average 17.37 bluefish (2.34 kg/tow) and an age-1+ index which averages 3.60 fish per tow (5.71 kg/tow). The surveys age-0 abundance initially was low during the startup years of the survey then varied around average levels from the late 80s to 1996. A three-year period of high abundance was observed from 1997 to 1999 after which abundance decreased to average levels. The age-1+ bluefish index declined steadily from above average levels in 1985 to 1.92 fish/tow in 1989. A large increase in abundance was seen in 1990 and again in 1992. A precipitous decline occurred for the next seven years to 0.86/tow in1999, the lowest abundance recorded. Abundance of age-1+ bluefish increased for the next three years to average levels in 2002. However, recent large catches of adult bluefish during the fall of 2004 resulted in a 21-year record high abundance (in numbers) that was five times higher than that seen just a year earlier and the second highest biomass index in the survey (Table 13; Table 14). Many of these fish ranged from 37 cm to 41 cm FL, however, catches of fish up to 70 cm FL were common in 2004.

4.4.6 New York DEC Small Mesh Trawl Survey

The New York Department of Environmental Conservation's (NYSDEC) Small Mesh Trawl Survey started in 1987. The survey area is divided into 77 sampling blocks located in the Peconic estuary in eastern Long Island. Each year from May to October, sixteen stations are randomly chosen each week and sampled by an otter trawl (16 foot shrimp trawl with small mesh liner) and towed for 10 minutes.

Catches of bluefish, which peak in August and September, consist almost entirely of young-of-the-year (52 to 250 mm FL). The highest observed catches occurred in the late 1980s, with a smaller peak in the mid-1990s. Catches of young-of-the-year have been well below average and declining in recent years (Table 13). A geometric mean number per tow was calculated from August and September tows as an index of bluefish abundance.

4.4.7 New York DEC Beach Seine Survey

In 1984, the NYSDEC initiated a beach seine survey, which was designed to target age-1 striped bass. The survey uses a 200 foot beach seine to sample about 175 sets per year from May through October at fixed stations within western Long Island bays, primarily Little Neck, Manhasset, and Jamaica bays.

Catches of bluefish are predominantly young-of-the-year and usually reach their highest abundance in July and August. An index of bluefish abundance was based on August hauls. Catches of young-of-the-year were highest in the late 1980s, 2000, and 2001. Catches of young-of-the-year have been below average in 2003 and 2004 (Table 13).

4.4.8 New Jersey DFW Ocean Stock Assessment Program

The New Jersey Division of Fish and Wildlife (NJDFW) Bureau of Marine Fisheries initiated the Ocean Stock Assessment Program in 1989 to monitor the abundance and distribution of marine recreational fishes in the state's nearshore coastal waters. The survey uses a stratified random design and is conducted five times per year in January, April, June, August, and October. The survey samples waters from Sandy Hook to the entrance of the Delaware Bay.

Typically, few to no bluefish are collected during the January and April surveys. Annual numbers of bluefish per tow range from 0.3 to 10.6. The highest years of abundance were 1989 (10.6 bluefish per tow), 1994 (8.1), and 2002 (7.8). The lowest years of abundance were 2001 (0.3) and 1993 (0.9). Sizes range from 3 to 81 cm FL. The majority (75%) of bluefish were less than 31 cm FL. Indices of bluefish abundance and biomass was calculated as the geometric mean per tow from the October data (Table 13; Table 14). Indices were further divided into age groups by applying the generalized age keys to survey length data (Table 15). Indices at ages greater than 2 prior to 1998 were unavailable.

4.4.9 Delaware DFW Juvenile Trawl Survey

Delaware's Department of Natural Resources and Environmental Control (DNREC) Division of Fish and Wildlife's juvenile trawl survey targets juvenile fish and shellfish. This program was initiated in 1980 to monitor distribution, relative abundance, and year-class strength. The survey conducts monthly sampling from April to October at fixed stations in the Delaware Bay and River. Tows conducted during September were used to estimate an index of abundance as the geometric mean number per tow (Table 13).

4.4.10 Delaware DFW Adult Trawl Survey

The DNREC Division of Fish and Wildlife began an adult trawl survey in 1966. The survey was discontinued in 1971, started again in 1979, discontinued after 1984, and finally resumed again in 1990. The aim is intended to track temporal trends in abundance and distribution and to characterize the size composition of select species. Trawl tows are carried out monthly from March to December at fixed stations in the Delaware Bay. Large numbers of bluefish are not common, but bluefish do occur in the catches, peaking in the fall. Tows from August to October were used to calculate the geometric mean number per tow and biomass per tow as indices of bluefish abundance (Table 13; Table 14). Abundance indices were further divided into age groups (Table 15). Only fish age 0 to age 2 were included due to samples sizes.

4.4.11 Maryland DNR Juvenile Striped Bass Seine Survey

The Maryland Department of Natural Resources' (MD DNR) Juvenile Striped Bass Seine Survey has documented annual year-class success and relative abundance of many fish species in Chesapeake Bay since 1954. Juvenile striped bass indices are developed from sampling at 22 fixed stations located in major spawning areas in Maryland's portion of the Chesapeake Bay. A subset of 13 sample sites was selected for the development of a juvenile bluefish index from 1981 to present. Other sites were excluded on the basis that bluefish were rarely, if ever, captured there. Each site is visited monthly, from July to September, and two samples are collected.

Samples are collected with a 30.5 m x 1.24 m bagless beach seine of untreated 6.4 mm bar mesh set by hand. Selected fish species are separated into age-0 and age-1+ groups. Ages are assigned from length frequencies and verified through scale examination. A random sub-sample of 30 age-0 fish is measured per site, per month. All other finfish are identified to species and counted. Additional data collected at each site include: time of first haul, maximum distance from shore, surface water temperature, surface salinity, primary and secondary bottom substrates, percent submerged aquatic vegetation, dissolved oxygen, pH, and turbidity.

Effort was slightly variable prior to 1994 because sites were occasionally lost to beach erosion, bulk heading, or proliferation of bay grasses. The number of samples has been constant (n=75) since 1994, and sample sites were standardized in 1997. Samples collected in July were used to generate an index of bluefish abundance (Table 13).

4.4.12 VIMS Juvenile Bluefish Seine Survey

Virginia Institute of Marine Science (VIMS) developed a program to survey the abundance of juvenile bluefish in the waters along the bay and ocean sides of Virginia's Eastern Shore. Data are collected in waters with depths up to 1.5 m. The survey was started as an extension of the striped bass beach seine survey and was granted funding in 1994. A seine is used to sample fixed stations from June to October. Data collected in September are used to calculate an index of bluefish abundance as the geometric mean number per haul (Table 13).

4.4.13 SEAMAP

The Southeast Area Monitoring and Assessment Program (SEAMAP) fishery-independent trawl survey has sampled the coastal zone of the South Atlantic Bight between Cape Hatteras, North Carolina and Cape Canaveral, Florida since 1989. The R/V Lady Lisa is used to conduct sampling. Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1-hour after sunrise to 1-hour before sunset). Stations are randomly selected from a pool of stations within each stratum. Beginning in 2001, the number of stations sampled in each stratum was determined by optimal allocation stations within fourteen shallow water strata in both summer and the fall. A total of 52 stations were sampled from 1990 to 2000 and increased to 57 after 2000. Sampling stations are delineated by the 4 m depth contour inshore and the 10 m depth contour offshore. In 2001, sampling stations in deeper strata were eliminated in order to intensify sampling in the shallower depth zone. Sampling occurs in spring (early April - mid-May), summer (mid-July - early August), and fall (October - mid-November). SEAMAP collects biological information for 27 priority species and the contents of each net are sorted separately to species. In every collection, each of the priority species is weighed collectively and individuals are measured to the nearest centimeter. Sub-sampling is used when catch of a priority species is too large to measure every individual.

Indices determined in this study were based on young-of-the-year bluefish (<25 cm FL) collected from inshore strata during April. Also, samples from south of 30°N were eliminated from analyses due to low and sporadic catches of bluefish in the southern range of the survey. Although older bluefish are occasionally collected, age-0 fish greatly predominate. The indices suggest above average age 0 abundance in 1991,1992 and 1995 (Table 13; Table 14)

4.5 General Survey Results

The seasonality of bluefish spawning results in two annual cohorts often referred to as the spring cohort and summer cohort (Chiarella and Conover 1990). Young-of-the-year survey indices were partitioned into cohort based on size (summer cohort = 1-13 cm, spring cohort = 14-25 cm) (Table 16).

The fishery-independent surveys sample components of the bluefish stock with distinct seasonal migration patterns that vary by fish age. State and federal fisheries-independent survey data were normalized to compare trends among young-of-the-year indices (Figure 8). Correlations among cohorts and programs were examined, resulting in 210 comparisons (Table 17). Among the comparisons, 17 of 210 possible combinations had R-values exceeding 0.5. However, 50% (105 of 210) were negatively correlated with another index (Table 17).

Because the state indices measure temporal and spatial components of a migratory stock, the size and contributions of these components to the total stock cannot be quantified.

4.6 Data Discussion

The Bluefish Technical Committee evaluated the quality of the commercial, recreational, and age data for use in an analytical model. The highest amount of commercial sampling since 1997 occurred in the North Carolina and Virginia region, which also accounted for the highest proportion of landings. The committee felt the sampling amounts by gear and market grade were adequate to represent the length distribution of Atlantic coast bluefish landings. The amount of commercial sampling in the mid-1990s was poor (see SAW-23 report), however, it was believed that here was enough information covering the entire time series to capture the trends in size for landings since 1982.

The length sampling of recreational landings has remained relatively stable at about 3,000 to 4,000 fish per year from 1997 to 2004 (Table 7). Since bluefish landings are not rare events, intercepts likely provide representative information to characterize length distributions. The MRFSS provides a survey estimate with proportional standard error estimates. The average PSE values since 1994 for bluefish (4.2) was comparable to other species such as summer flounder (3.9) and striped bass (5.3). The Committee concluded that the recreational landings information was adequate for use in a bluefish assessment. Recreational discard estimates were also considered adequate although there remains a lack of discard length information.

Age information, although relatively sparse in some years, was determined to be adequate to characterize bluefish catch and indices. Bluefish growth is dominated by the increase in size at age-0 and age-1. The fast growth results in very strong signals within the length distributions with little overlap between cohorts. The committee accepted the recommendation of researchers that ages beyond age-6 based on scales may underestimate the true age. The committee concluded that although there may be some error introduced into analytical models due to combining age data across years it was not likely a fatal flaw in this instance.

Most state agencies between Massachusetts and Florida conduct some type of annual survey of marine finfish. Examination of the survey results did not reveal any consistent signal of bluefish abundance or biomass indices among programs. There appears to be several issues that create problems with bluefish survey data. First, the type of gear used in available survey programs (trawls or beach seines) is generally inefficient for catching bluefish, particularly once the fish reach a larger size and can easily evade the gear. The second problem is the wide-distribution of the bluefish stock along the Atlantic coast. Finally, there appears to be a partitioning of fish by size, with smaller fish most common inshore and larger fish most common in deeper offshore areas. Consequently, state coastal surveys tend to miss larger fish that are beyond the survey area. In addition, during the fall survey period individual state programs only sample a limited part of the population. The NEFSC inshore survey reduces some of the problem associated with temporal coverage, although there remains the issue of catchability of larger fish.

The relationship among age-0 bluefish indices from different programs may be further confounded by the strength of the juvenile cohort (spring vs. summer) that is being sampled. The correlations suggest that summer cohorts may produce similar signals among the northeastern states surveys, but with little correlation among spring cohorts. The mix of the spring and summer cohorts within an age-0 index may produce indices without a clear signal of abundance trends.

The Technical Committee concluded that although there was inherent uncertainty in the data, the data was adequate for use in an analytical model. The greatest area of uncertainty was in the accuracy of survey indices in following population trends. The committee felt that the recreational CPUE, although a fishery-dependent index, provided the greatest spatial coverage and had the least problem with catchability of larger fish. The approach was to evaluate the utility of each survey index based on their performance within a model framework.

5.0 TERM OF REFERENCE #2: Evaluate adequacy and appropriateness of models used to assess the species and to estimate population benchmarks.

After reviewing several model types such as the modified Delury model, a surplus production model, a VPA and catch-at-age models, the Committee concluded that age-based models such as a catch-at-age model or VPA model were most appropriate for a bluefish assessment (see appendix I for details on rejected models). The bluefish data were truncated to an age-6+ category to reduce the influence of ageing error. In addition, the catch-at-age distribution in past assessments has been identified as having a bimodal distribution, which was reduced with inclusion of more ages into a plus group.

The NFT ADAPT version of VPA was used as an initial model. The model is configured such that a partial recruitment vector is input for use in estimation of terminal year + 1 *F* and N. However, estimation of the oldest true age in the matrix in prior years does not account for a dome (or bimodal) shaped partial recruitment (PR) vector. An *F*-ratio other than 1 for calculation of the plus group *F* can help adjust for non-flat topped PR in the plus group. The ADAPT model was setup to use averaging within years rather than across years to avoid some issues associated with any bimodal PR.

The Committee concluded that although the VPA produced satisfactory results, the assumption of no error in the catch-at-age matrix and the way ADAPT handles selectivity may produce misleading results. Therefore, a catch-at-age model, ASAP from the NFT models, was chosen as the primary assessment tool. The ability of the ASAP model to allow error in the catch-at-age as well as the assumption of separability into year and age components makes it better suited to handle the selectivity patterns and catch data from the bluefish fishery. However, there is no diagnostic metric that allows direct comparison between ADAPT and ASAP models.

6.0 TERM OF REFERENCE #3: Evaluate and either update or re-estimate biological reference points as appropriate.

The biological reference points in the FMP were based on a surplus production model that was rejected during the SAW 39 review. Therefore there are no currently accepted reference points for Atlantic coast bluefish.

New biological reference points were developed for comparison to current stock status. The preferred ASAP model output estimated F_{MSY}=0.19 (Table 18). The model also estimated F_{MAX} = 0.28, $F_{0.1}$ = 0.18 and $F_{30\%}$ as 0.28 (Table 18). Alternative reference points were calculated with an age based Thompson-Bell yield-per-recruit model (Figure 9). Partial recruitment values were based on the average 1982-2003 ASAP selectivity estimates. The model was extended to age-7+ with a selectivity of 1.0. F_{MAX} was estimated at 0.25, $F_{0.1}$ = 0.17 and $F_{30\%}$ as 0.26 (Table 18). The current F of 0.146 is below F_{MSY} as well as alternative reference points. Therefore, it is concluded that bluefish is not experiencing overfishing.

Recruitment and spawning stock biomass are both estimated in the ASAP model and these values used to fit a Beverton-Holt S/R relationship. The parameters for bluefish were alpha = 35426.6 and beta = 41159.4 with a steepness of 0.7399 (Figure 10). In addition, SSB at msy was estimated equal to 142.1 million lbs. Using the SSB/R and B/R estimates from the Thompson-Bell model, we used the Shepherd/Sissenwine approach to calculate B_{msy} as 147.05 million pounds (Table 18). The current FMP defines overfished status as biomass below ½ B_{msy} which would be equal to 73.52 million pounds (Table 18). Therefore, with the current estimate of biomass equal to 104.1 million pounds, bluefish would not be considered overfished.

7.0 TERM OF REFERENCE #4: Estimate and evaluate stock status (biomass) and fishery status (fishing mortality rate). Is the stock overfished; is overfishing occurring?

7.1 ADAPT model

The initial bluefish model was the ADAPT VPA using a catch-at-age matrix from 1982 to 2004 through age-6+. The SAW-17 review of a bluefish assessment suggested that values of M should range from 0.2-0.25 instead of M=0.35 (NEFSC 1994a). Since the oldest aged bluefish is 14, an M of 0.2 was appropriate, using M=3/oldest age. The initial input PR was bimodal with a maximum value at age-1 of 1.0 and age-5 value of 0.74. The F ratio was set at 1.4 to create a higher F in the age-6+ group, forcing the model towards a bimodal F pattern. Full F was calculated as an average of F from age-2 to age-4 (since age-5 F was based on oldest true age estimation and age-6+ was function of the oldest true age).

Maturity at age was held constant over time as 0 at age-0, 0.25 at age-1, 0.75 at age-2 and 1.0 thereafter. Following initial runs including all available indices, the tuning indices were truncated based on proportional variance contributions to the overall model variance. The final tuning indices were limited to those with adults present (NEFSC inshore (age-0 – age-6+), CT trawl indices (age-0 – age-6+), NJ trawl indices (age-0 – age-2), DE adult trawl indices (age-0 – age-2), Rec CPUE (age-0 – age-6+), and the SEAMAP series to include an age-0 recruitment series from the South Atlantic Bight. Tuning was made to mid-year population size.

Results of the ADAPT indicate a reasonable fit to the model with a CV around the population estimates of 0.43 (age-0), 0.38 (age-1), 0.27 (age-3 and age-4) and 0.28 (age-5). The model fit to the indices tended to miss the abrupt peaks in the time series. The residual patterns for Rec CPUE age-1 and age-2 had a trend over time. However, when indices were removed from the model they had little influence on the results (the population CVs increased to 0.30 for age-3 – age-5). The fishing mortality rate in 2004 was estimated to be F_{2004}=0.12, a decline from 0.23 in 2001 (Table 19). Population size estimates increased steadily from 52,940 in 1998 to 97,216 in 2004 (using a geometric mean recruitment estimate since 2000) (Table 20) and biomass estimates increased from 47.9 million lbs in 2000 to 90.4 million lbs in 2004 (Table 21). Bootstrapped abundance estimates produced an 80% confidence interval of 78,793 to 108,963 thousand fish and a January 1 biomass distribution of 86.0 million to 140.9 million pounds (Figure 11). Similar bounds in *F* estimates ranged from 0.10 to 0.16 (Figure 11). The model configuration had no retrospective pattern in the *F* or population estimates (Figure 12)

7.2 Age-Structured Assessment Program (ASAP)

The input values from ADAPT were used as initial values for the ASAP model. ASAP allows selectivity and catchability patterns to vary over time. The model was structured to allow greater deviations from the indices than from the catch-at-age data. A selectivity pattern was fitted to the data and held constant for the periods 1982-1990,1991-1998 and 1999-2004. Recruitment was allowed to deviate from the fitted model after the 4th year.

The final model configuration resulted in a residual sum of squares of 0.0035 and a likelihood value of 7.058 (Table 22). When the model is allowed to vary selectivity to fit catch data, the resulting selectivity pattern was similar to the backcalculated PR in the ADAPT results and did not vary over time. The model closely predicted catch at age for the combined time series and annual catch when compared to the observed catch (Figure 13). Annual catch at age predictions were less accurate, particularly in years with unusually high or low age-0 and age-1 catch (Figure 14).

Predicted indices vary from observed estimates, in part because of the weighting schemes used in the model. Predicted indices are generally smoothed over time relative to observed values (Figure 15). Negative log-likelihood values were minimized for recreational CPUE at age, CT age-0 and DE age-1 (Figure 16). Similar to ADAPT, the early part of the REC age 1 time series was under-estimated. Overall the residual patterns scattered distributions with the exception of time trends in age 1 and age 2 recreational CPUE indices (Figure 17)

Fishing mortality estimates in ASAP are based on a separability assumption. F_{MULT} is the estimate of full F. The 2004 F_{MULT} value equals 0.149 (Table 23) . The trend in F has steadily declined since 1991 when F reached 0.41 (Figure 18). The time series of F from the VPA shows less variability since 1990, bounded between 0.1 and 0.23. If the average VPA F for ages 1-4 is compared to ASAP average F for the same ages, the resulting F trends between the two models are very similar.

January 1st population sizes show a general increase in overall abundance since 1997 (Table 24; Figure 19). Abundance estimates peaked in 1982 at 176 million fish, declined to 57 million in the mid-1990s and has since increased to 92 million fish (Table 19). Biomass estimates peaked in 1982 at 220.0 million lbs, then declined to 65 million lbs by 1997 before increasing to the 2004 level of 104 million lbs (Table 25; Figure 20). The magnitude of population estimates are similar to those produced in the VPA.

8.0 CONCLUSIONS

The Bluefish Technical Committee concluded that the results of the ASAP model were the best representation of the Atlantic coast bluefish population. There was some trade-off in the goodness of fit between the catch-at-age and survey indices in the model, but the overall model results were considered acceptable. The results also corresponded well to ADAPT model results. Although the agreement between models did not validate either model, it indicates that there was some signal in the data that could produce consistent output in two models with different assumptions. The model results lead to the conclusion that the Atlantic stock of bluefish is not experiencing overfishing nor is it overfished.

9.0 RESEARCH RECOMMENDATIONS FROM SAW 39 PANEL

Data

Release Mortality

- The mortality of bluefish released by anglers is a key parameter because of the large proportion now released alive, and should be the subject of a more detailed investigation. This should include effect of any potentially significant factors such as fish size, sex, method of capture, and season.
    - No new studies have been conducted since SAW 39.

Recreational Catch Rate

- Recreational catch rate is important, so the data should be collected in a manner that allows analysis of changes in angler behavior, composition, technology, or other factors that influence both the statistical distribution of individual catch rate and changes in catchability over time.
    - Data collection made under the MRFSS program with a standard sampling protocol. That protocol has not been changed.

- Terceiro (2003) has done much of the groundwork needed to develop a recreational catch rate abundance index. Poisson quasi-likelihood may be the simplest error model to apply. If possible, all trips should be used, and targeting should be allowed for as factor in the GLM.

- The Terceiro method was used in calculation of recreational catch rates for the current analysis.

Catchability

- An assumption of constant catchability in recreational catch rates is likely to give an optimistic view of the state of the stock unless there has been a significant increase in less efficient anglers over time, and must remain an issue of concern that needs to be addressed externally to the model, through a more comprehensive analysis of recreational catch data.
    - The change in angler efficiency is partially addressed through use of the GLM model. However, a lack of angler specific information prohibits detailed analysis of changes in catchability.

Indices

- Catch rate and survey indices should both continue to be used for assessment purposes, if possible. However, models other than a catch rate index should at least be considered.
    - Recreational catch rates and survey indices were used in the current assessment, which is a forward-projecting age-structured model.

- There is a need for an integrated analysis of the many different research surveys for juvenile bluefish. The surveys cover different regions using different gear types and provide data on 0- and 1-group bluefish. It is recommended that serious consideration be given to convening a workshop to evaluate: 1) the quality of the individual data sets; 2) the potential ability of the surveys to index bluefish abundance at age in the areas surveyed; 3) coherence of trends in localized surveys with trends in nearby stations of the larger scale surveys; and 4) methods for standardizing and combining data from small-scale intensive surveys with large-scale less spatially intensive surveys, to give improved indices of recruitment. Such a workshop would require consolidation of raw survey data from the different surveys into common databases.
    - An attempt was made to consolidate state survey data into a single comprehensive index. Available data limited progress on the analysis at this time. It has been suggested to the ASMFC that a workshop to conduct this consider this approach is warranted.

Age Data

- Age composition data should be collected to allow continued development of fully age-structured assessment models, particularly in light of the unusual selectivity patterns estimated from earlier catch-at-age analyses.
    - Data collection continues but limited efforts have been made towards generating coast wide age information.

Maturity

- Maturity ogives need to be constructed and presented in future assessments.
    - This has not been done to date.

Tagging Studies

- The feasibility of using tagging studies to estimate mortality, selectivity and movements, as well as to determine tag retention, should be investigated.
  - o A manuscript regarding a tagging study of bluefish along the Atlantic coast is currently in review.

Catch Data

- Catches should not be presumed to be exact, but can be fitted through some likelihood function for discrepancies between observed and estimated catch in the population model. The likelihood can use the standard error of the catch estimate.
  - o This has been addressed through the use of the ASAP model.

Use of GLM

- Care should be taken when using a GLM index approach that information relevant to changes in stock size is not mistakenly removed. A better approach might be to integrate the GLM into a population model.
  - o Only the recreational CPUE was subjected to a GLM analysis in this assessment. Fisheries independent indices were modeled by the assessment model.
  - o

International Work

- Stock assessment methods applied to bluefish elsewhere in the world should be evaluated for applicability to the NE US situation.
  - o An extensive search of international work found a recent assessment of bluefish conducted in Queensland, Australia had potential applicability to the US East Coast situation. Leigh and O'Neill (2004) applied three different stock assessment models to data collected from the Australian east coast tailor fishery to evaluate stock status. Results of a surplus production model were considered unreliable. The main concerns with the outcome of the various model scenarios were parameter estimates that were unrealistic for tailor, the surplus production method's inability to model partial selectivity of mature fish, and convergence on local minima. An age-structured model and a fully integrated age-length model were also evaluated. The age-length model structured the population by both length and age. The development of the age-length model was prompted by a desire to capture the observed changes in length-at-age of tailor over the years. Unlike the strictly age-structured model, this model is able to directly fit observed length frequencies rather than first converting them to ages. Ageing data are applied only in years when age data are available, instead of extrapolating to years with missing age data.
  - o The current data available for the US east coast bluefish stock could support development of an age-length model. Commercial and recreational fishery length samples are available back to 1982 and at least seven fishery-independent surveys have collected 20 or more years of length data on bluefish. North Carolina has 13 years of age data based on scales and 5 years of otolith-based ages. Virginia has been processing otolith ages since 1998. Application of a fully integrated model could incorporate all these data and avoid some of the disadvantages of age-structured analyses. It would not be necessary to combine age-length keys

across years, or even gear type depending on the model configuration. Other advantages include ability to model selectivity patterns as a function of size, incorporation of variation in size-at-age, and ability to include an explicit growth function.
    - Leigh, G.M. and M.F. O'Neill. 2004. Stock assessment of the Queensland-New South Wales Tailor Fishery (*Pomatomus saltatrix*). Queensland Department of Primary Industries and Fisheries QI04065.

<u>Intermediate Models</u>

- Pending ability to apply full age-structured methods, the use of partially age-structured methods such as the Collie-Sissenwine model is recommended to allow explicit incorporation of survey estimates for 0- and 1-group fish, so estimating the contribution of recruitment to annual production. This would require that the commercial fishery and recreational catches and cpue be disaggregated into recruits and older fish. The effect of poor data on discards of young bluefish in the commercial fishery on such an analysis requires evaluation.
    - A Collie-Sissenwine model was attempted in this assessment (see appendix). However, it was not successful for various reasons. A modification of the model structure in future work may eliminate the issues identified.

<u>Model Optimization</u>

- Global search algorithms (e.g. genetic algorithms) should be used for parameters if an ASPIC model is used in future.
    - ASPIC was not the model of choice in this assessment. Recent changes have been made to the search algorithm in the NFT ASPIC software.

<u>Management</u>

- As the current assessment has been rejected, and the status of the stock is unknown, the total allowable landings specification should continue at current value.
    - Management has been status quo since the assessment was rejected.

- Reducing fishing mortality to allow the abundance indices to increase could provide useful information on the productivity of the stock. A much-improved assessment may be obtained when a recovery has taken place.
    - No action taken.

10.0 TERM OF REFERENCE #5: Research Recommendations

Commercial Data

- Increase sampling of size and age composition by gear type and statistical area
- Target landings for biological data collection and increase intensity of sampling for biological data.

Recreational Data

- Increase sampling of size and age composition by gear type and statistical area
- Target landings for biological data collection and increase intensity of sampling for biological data.

Ageing Data

- Complete a scale-otolith comparison study
- Conduct study or workshop to address discrepancies between estimated bluefish age from scales and otoliths and the chronological age. Examine issues of inter- and intra-reader variation in interpretation of ages
- Examine the feasibility of each state collecting samples of hard parts for ageing, with one or two laboratories interpreting the annuli for consistency.

Fishery-Independent Data

- Continue research on species interactions and predator-prey relationships
- Examine alternative weighting schemes for the available fishery-independent surveys (*e.g.* area, inverse variance, N, etc.)
- Investigate the feasibility of alternative survey methods that target bluefish across all age classes to create a more representative fishery-independent index of abundance
- Initiate sampling of offshore populations in winter months
- Conduct research on influences on recruitment including pathways of larval bluefish
- Initiate coastal surf zone seine study to provide more complete indices of juvenile abundance.

Models, Inputs, and Outputs

- Explore a tag based assessment and associated costs compared to age based assessments
- Determine if a tag based assessment could supplement or replace other assessment techniques
- Continue to examine alternative models including a forward projection catch-at-age model.

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